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Insecticide resistance study in *Plutella xylostella* L.

II. A general survey (1980-81)[1]

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Abstract : A general survey of resistance in diamondback moth, *Plutella xylostella* L., to five commonly used insecticides in Taiwan was conducted from December 1980 to April 1981. Started from northeast down to southwest of Taiwan, along the west coast, we had sampled twenty-one districts; two adjacent districts were approximate twenty kilometer apart.

The highest resistance ratio was 32.5 for carbofuran, 10.9 for mevinphos, 3.6 for cartap, 48.5 for permethrin and 75.0 for fenvalerate. Geographically, the resistance problem was more serious in south than the north and the high ground regions were less troubled than the intensively cultivated vegetable growing areas.

In an overall analysis of both the intensity and the complexity of resistance in the diamondback moth, we found that out of all the districts which were investigated, 19% with serious trouble, 47% with some problems, 24 % with minor problem and only 10% without significant resistance problem.

Practically, the diamondback moth, *Plutella xylostella* L. has developed resistance to almost all the insecticides which were recommended in controlling this pest in Taiwan. A thorough understanding of the problem will help a great deal to plan a better pest management program in the near future. Taiwan Agricultural Research Institute has developed a suitable sampling method for surveying the resistance of diamondback moth in a rather large area[(2)]. The general survey of resistance was conducted from December 1980 to April of the following year. Five commonly used insecticides were tested for the resistance level ; a general view of insecticide usage in the diamondback moth control were evaluated as well.

Materials and Methods

The diamondback moth was collected from each sampling district following the sampling

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method which we had established previously [2]. Total of two to three hundred of matured larvae and pupae were collected from five separated cruciferous fields within a limit of five thousand hectare. Insects were brought back to the laboratory and reared on insecticide-free cabbages to the adult stage; the adults were fed with honey-water mixture daily. After mating, females oviposited their eggs on a potted cabbage in the screen cage. Only the third instar larvae of F_1 generation of collected insects were used in the LC_{50} determination and the insecticide treatment was conducted in a Potter Spray Tower.

Started from northeast (IL-strain) down to southwest (LY-strain) of Taiwan, along the west coast, we had sampled twenty-one vegetable growing districts (Fig. 1); two adjacent districts were approximate twenty kilometer apart.

We selected carbofuran, cartap, fenvalerate, mevinphos and permethrin for this investigation because they were officially recommended insecticides for the diamondback moth control in Taiwan. Carbofuran and mevinphos in commercial formulated products were diluted in water to different concentrations for the test.

Cartap, fenvalerate and permethrin were obtained from industrial suppliers in 95% technical grade. For the test, cartap was dissolved in a mixture of acetone and water (1 : 1, v/v); fenvalerate and permethrin were dissolved in acetone.

In spraying, one milliliter of insecticide solution was pipetted into the solution-holding tube of the tower; when we switch on the spraying control, the solution was sucked into a stainless steel U-tubing and sprayed out from the nozzle into the tower. After spraying, we waited for ten seconds before lowering the stage to take out the objects. The solution-holding tube was rinsed throughly two to three times with a proper solvent whenever the concentration or the insecticide was changed.

In testing carbofuran or mevinphos, one side of a cabbage leaf was sprayed with insecticide first and then we loaded insects on the other side of leaf and sprayed again. In cartap test, insects were not sprayed, instead they were fed with a piece of throughly sprayed cabbage leaf. In the tests of fenvalerate and permethrin, only the insects were sprayed with insecticides.

For any insecticide LC_{50} determination, approximate ten concentrations were tested on each sample population.

Twenty third-instar larvae were used in one replica with two replicas for each concentration; the sum of two replicas were subjected for the probit analysis. The insect mortality was counted twenty-four hours after the treatment and the post-treatment condition was controlled at $25\pm1°C$ and $80\pm5\%$ in relative humidity.

In calculating the resistance ratio, the IL-strain was used as the susceptible strain because it was more susceptible than the laboratory strain [2] to all five tested insecticides.

When we mapped the resistance distribution pattern, the resistance ratio were graded into five classes according to its magnitude and they were 1-2, 2-5, 5-10, 10-20 and 20 plus.

Results

The complete results of this survey was presented in Table 1. It is clear that the diamondback moth has developed resistance to insecticides in most of places and the resistance level were alarmingly high in some regions. The highest resistance ratio was 32.5 for carbofuran, 10.9 for mevinphos, 75.0 for fenvalerate, 3.6 for cartap and 48.5 for permethrin. Since the samples were equally distanced and covered the whole west coast of Taiwan, it is possible to take an average of all samples to examine the overall situation ; the averaged ratio was 10.125 for carbofuran, 4.47 for mevinphos, 2.185 for cartap, 34.12 for fenvalerate and 19.5 for permethrin.

Table 1. The resistance of twenty-one field strains of diamondback moth, *Plutella xylostella* L. to five commonly used insecticides .

Field location	Level of resistance									
	Carbofuran		Cartap		Fenvalerate		Mevinphos		Permethrin	
	LC_{50}[a]	RR[b]	LC_{50}	RR	LC_{50}	RR	LC_{50}	RR	LC_{50}	RR
IL —	42	1.0	250	1.0	134	1.0	64	1.0	104	1.0
ST —	1,367	32.5	531	2.1	7,546	56.3	332	5.2	4,624	44.5
SH —	279	6.6	536	2.1	526	3.9	90	1.4	334	3.2
TY —	212	5.0	455	1.8	1,165	8.7	109	1.7	568	5.5
CP —	499	11.9	406	1.6	3,323	24.8	255	4.0	904	8.7
ML —	236	6.7	527	2.1	1,907	14.2	284	4.4	751	7.2
TC —	434	10.3	382	1.5	4,579	34.2	304	4.8	1,248	12.0
TT —	250	6.0	679	2.7	2,443	18.2	271	4.2	1,139	11.0
PL —	280	6.7	368	1.5	2,820	21.0	265	4.1	895	8.6
SL —	327	7.8	895	3.6	1,603	12.0	201	3.1	556	5.3
HH —	258	6.1	542	2.2	3,815	28.5	321	5.0	5,041	48.5
HL —	469	11.2	558	2.2	5,289	39.5	412	6.4	3,991	38.4
PC —	162	3.9	481	1.9	4,322	32.3	251	3.9	1,346	12.9
MH—	208	5.0	531	2.1	4,612	34.4	190	3.0	1,360	13.1
PT —	339	8.1	526	2.1	9,690	72.3	330	5.2	2,545	24.5
HY —	358	8.5	646	2.6	9,448	70.5	193	3.0	2,243	21.6
MT —	213	5.1	647	2.6	8,724	65.1	303	4.7	1,227	11.8
LC —	836	19.9	723	2.9	5,700	42.5	699	10.9	3,792	36.5
KS —	343	8.2	414	1.7	3,134	23.4	224	3.5	1,237	11.9
NP —	649	15.5	420	1.7	755	5.6	219	3.4	2,034	19.6
LY —	736	17.5	687	2.7	10,055	75.0	477	7.5	4,705	45.2

a. concentration of insecticide (in ppm).

b. resistance ratio to the IL-strain.

The resistance intensity in regard to the sample location was mapped in Fig. 1 to 5. In these figures, we can find the coverage and the intensity of resistance in different field strain of diamondback moth. We further examined the survey results in a correlati on test and the test result proved that there were strong correlation among the resistance intensity of different insecticides from the same sample site. This fact indicated that not only the intensity but also the complexity of chemical control had contributed to the

resistance problem.

In order to examine the overall situation, we designed an analysis system to demonstrate the combined effect of intensity and complexity of resistance. In this system, we averaged the resistance rating of cartap, carbofuran, mevinphos and synthetic pyrethroid as one combined single rating. The synthetic pyrethroid rating was the average of fenvalerate and permethrin. The result was presented in Table 2 and the values were ranged from 1.0 to 3.75; again they were classified into four sub-ranges of 1-1.75, 1.75-2.50, 2.50-3.25 and 3.25-4.00 and we artificially defined them as properly, frequently, intensively and overly in the insecticidal usage for the diamondback moth control. The rating in relation to the sample location was mapped in Fig. 6, in hoping to gain a better understanding of their geographic distribution pattern. The IL-strain and TY-strain both belonged to the group with least problem in resistance; the SH-strain, the PL-and SL-strain combination, the PC-strain and the KS-strain belonged to a same group with minor resistance problem; three mostly troubled regions emerged in the map were the areas covered by the ST-strain, the HL-strain and a rather spread out region which harbored the LC-strain and LY-strain. Rest of investigated regions formed the lar gest group with some problems in resistance in the diamondback moth control.

Table 2. The combined rating of intensity and complexity of resistance in twenty-one field strains of diamondback moth. *Plutella xylostella* L. in Taiwan.

Field location	Resistance rating in intensity				Overall average	
	Carbofuran	Cartap	Mevinphos	Syn. pyrethroid		
IL —	1	1	1	1	1.00	P
ST —	5	2	3	5	3.70	O
SH —	3	2	1	2	2.00	F
TY —	2	1	1	3	1.75	P
CP —	4	1	2	4	2.75	I
ML —	3	2	2	4	2.75	I
TC —	4	1	2	5	3.00	I
TT —	3	2	2	4	2.75	I
PL —	3	1	2	4	2.50	F
SL —	3	2	2	3	2.50	F
HH —	3	2	2	5	3.00	I
HL —	4	2	3	5	3.50	O
PC —	2	1	2	5	2.50	F
MH —	2	2	2	5	2.75	I
PT —	3	2	3	5	3.25	I
HY —	3	2	2	5	3.00	I
MT —	3	2	2	5	3.00	I
LC —	4	2	4	5	3.75	O
KS —	3	1	2	4	2.50	F
NP —	4	1	2	4	2.75	I
LY —	4	2	3	5	3.50	O

P : properly F : frequently I : intensively O : overly in insecticide usage.

Discussion

In 1975, Chang [1] first reported that the diamondback moth had developed resistance to organophosphorus insecticides in Taiwan and the resistance ratio was ranged 7.6-19.4 for mevinphos, 3.3-11.7 for DDVP, 7.7-9.0 for malathion and 6.0-6.3 for parathion. Lee and Lee [5] continued the study and reported that the ratios were ranged 2.0-16.0 for malathion, DDVP, diazinon, elsan, and mevinphos. Chi and Sun [3] reared a susceptible strain to determine the diazinon resistance and the highest level they measured was 14.0 which coincided with the highest resistance in the field strain. Although the resistance in tobacco budworm have increased 200 folds toward methyl-parathion [7] ; the same situa tion has not happened in the diamondback moth yet because the resistance to organopho sphates in the diamondback moth reported so far has not reached 20 folds. The simi larity of both Lee and Lee's report and our survey has demonstrated that the resistance of diamondback moths to organophosphates can or has reached an equilibrium in the field condition. Since Lee and Lee's result also indicated that there were similarity among the level of resistance to five organophosphates of different strains ; the survey result of mevinphos may also reflect what was happened to most of other organo phosphates. In the case of carbamate, Feng and Sun [4] had studied the methomyl resistance and reported that ratio was ranged from 2.8 to 14.0 with an average of 8.0.

In our study, the resistance for carbofuran was some what higher and the ratio was ranged from 3.9 to 32.5 with an average of 10.1. Although the relationship between the resistance mechanisms of carbofuran and methomyl is not clear so far, the resistance level of carbamates were two folds of those for the organophosphate ; in other words, the diamondback moth can develop a higher resistance to carbamates than organophosphates in field without much of explanation yet.

In the aspect of synthetic pyrethroid, the magnitude of resistance is much higher than both carbamate and organophosphate ; Liu et al [6] described that a field strain of diamondback moth gained 207 folds of resistance to fenvalerate, and the highest resista nce for permethrin, cypermethrin and decamethrin can also reasch 14.1, 87.3 and 67.1 respectively. Our survey indicated the same phenomenon that is the diamondback moth possess ability to develop higher resistance toward synthetic pyrethroids and the highest resistance ratio measured is 75.0 for fenvalerate and 48.5 for permethrin. Obviously, the resistance mechanism to synthetic pyrethroid may be different from those for ca rbamate or organophosphate. Although it is too early to deal with the so called distri bution pattern of resistance in concerning with any particular insecticide but some continuity of the resistance level can be found in Table 1 and Fig. 1-5. Several resistance-proned regions can be easily located on the maps ; based upon this fact that some kind of mapping system might able to be developed in the near future for monito ring and forecasting the resistance situation. Just as we had expected in our first study [2], cartap is the least resistance-troubled insecticide and the result of this survey proved that the diamondback moth has not developed serious resistance to this insecticide yet.

One surprising finding emerged from this study is that the insecticide resistance of diamondback moth is definitely a localized problem. As the IL-strain demonstrated that it was the most susceptible strain to all five tested insecticides ; on the other hand, several other field strains possessed strong resistance to almost all five tested insecticides. This fact matched the habit of most vegetable farmers who usually sprayed the field by mix ing several insecticides together. Our speculation is further confirmed by a correlation test. We believe the map which represents both intensity and complexity of insecticide usage in the diamondback moth control will help a great deal in the future pest manag ement design. The survey result will also directs the residue monitoring agency to co ncentrate their effort in the areas where insecticide was heavily used.

APPENDIX

Name Index of Sample Location.

IL-	I-Lan	宜蘭	HL -	Hsi-Lo	西螺
ST-	Sheh-Tzu	社子	PC -	Pao-Chung	褒忠
SH-	Shan-Hsia	三峽	MH-	Min-Hsiung	民雄
TY-	Ta-Yuan	大園	PT -	Pu-Tzu	朴子
CP-	Chu-Pei	竹北	HY -	Hsin-Ying	新營
ML-	Miao-Li	苗栗	MT-	Ma-Tou	麻豆
TC-	Ta-Chia	大甲	LC -	Lu-Chu	路竹
TT-	Tan-Tzu	潭子	KS -	Kao-Shu	高樹
PL-	Pu-Li	埔里	NP -	Nei-Pu	內埔
SL-	Shui-Li	水里	LY -	Lin-Yuan	林園
HH-	Hsi-Hu	溪湖			

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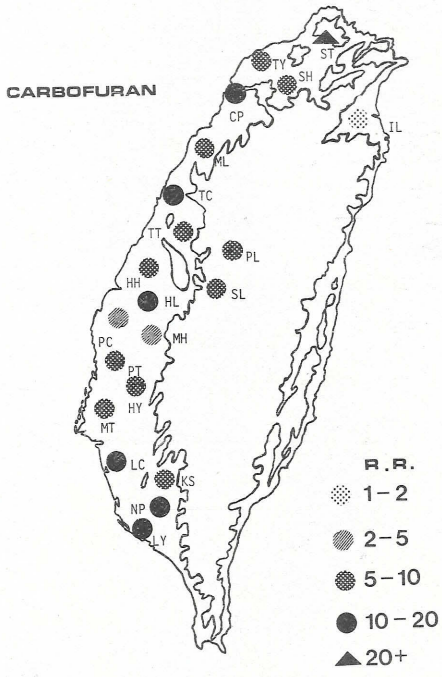

FIG. 1 THE GEOGRAPHIC DISTRIBUTION OF CARBOFURAN RESISTANCE IN THE DIAMONDBACK MOTH IN TAIWAN, 1980-81.

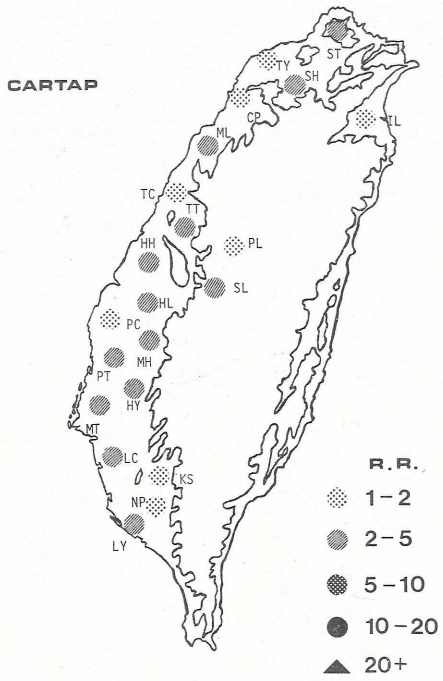

FIG. 2 THE GEOGRAPHIC DISTRIBUTION OF CARTAP RESISTANCE IN THE DIAMONDBACK MOTH IN TAIWAN, 1980-81.

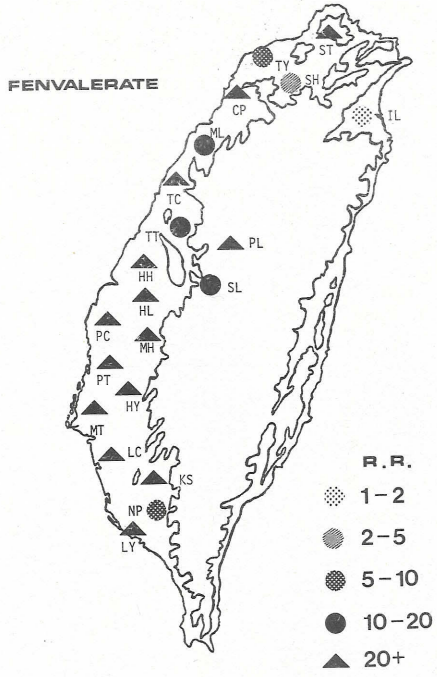

FIG. 3 THE GEOGRAPHIC DISTRIBUTION OF FENVALERATE RESISTANCE IN THE DIAMONDBACK MOTH IN TAIWAN, 1980-81.

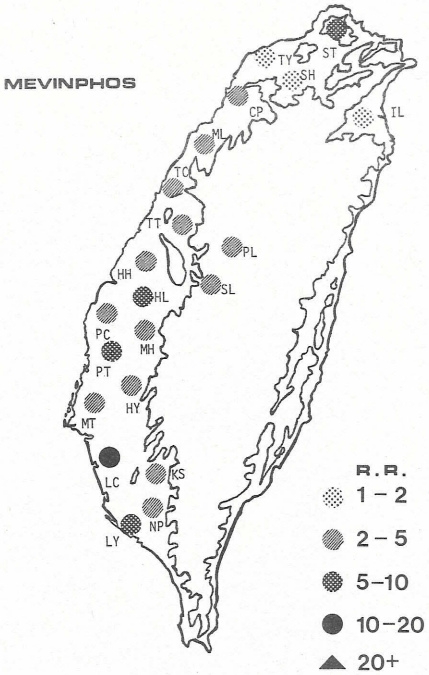

FIG. 4 THE GEOGRAPHIC DISTRIBUTION OF MEVINPHOS RESISTANCE IN THE DIAMONDBACK MOTH IN TAIWAN, 1980-81.

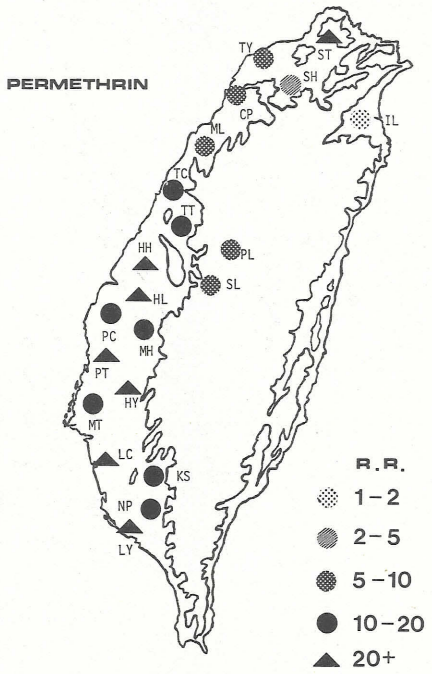

FIG. 5 THE GEOGRAPHIC DISTRIBUTION OF PERMETHRIN RESISTANCE IN THE DIAMONDBACK MOTH IN TAIWAN, 1980-81.

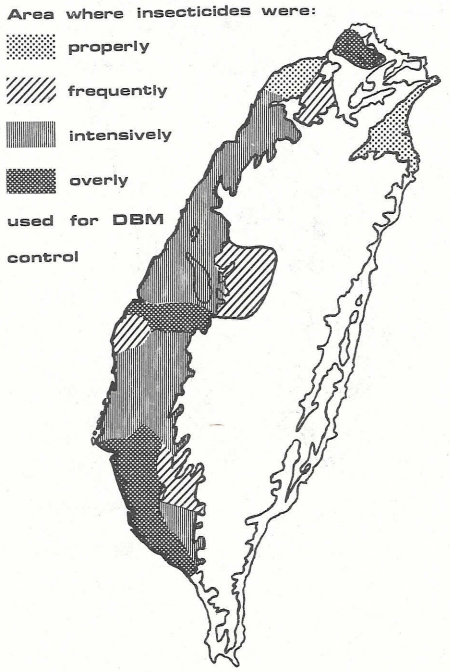

FIG. 6 THE COMBINED RATING OF BOTH INTENSITY AND COMPLEXITY IN THE DIAMONDBACK MOTH RESISTANCE TO INSECTICIDES IN EVALUATING THE CHEMICAL CONTROL MEASURE OF DIFFERENT LOCATIONS.

小菜蛾抗藥性之研究

Ⅱ. 全省調查結果及討論[1]

鄭　允[2]

中 文 摘 要

本所爲確實瞭解全省各地小菜蛾（*Plutella xylostella*）對現用殺蟲劑之反應，特於民國69年12月至70年4月間，進行抗藥性調查。執行計劃時，將全省自宜蘭至林園劃分爲21區，不含東部及梨山，於各地區依適當之取樣程序，採集小菜蛾樣本携返室內，測定其抗藥程度。測定用之殺蟲劑爲加保扶（氨基甲酸鹽類）、美文松（有機磷類）、培丹（有機氮）、百滅靈及芬化利（合成除蟲菊精類）等五種，均爲目前推薦於小菜蛾之殺蟲劑。結果顯示，各地區品系之抗藥程度，若以宜蘭品系爲基準，則抗加保扶程度爲1至32倍、抗美文松程度爲1至11倍、抗培丹者爲1至4倍、抗百滅靈者爲1至48倍、而抗芬化利者則爲1至75倍。抗藥性程度之地理分佈，除北部社子地區外，由北而南漸見嚴重。宜蘭品系對五種供試藥劑之感度均高，路竹及林園品系之抗性則偏高而且普遍。接近山區者則抗性較低，而專業區內之小菜蛾，均具較高抗性。若將每一地區樣本對各類殺蟲劑抗性高低及其普遍性混合計算時，可推算該地區農民用藥之頻度及其種類混雜程度。推算結果就小菜蛾抗藥性而言，全省19%地區殺蟲劑使用過度而有嚴重之抗藥問題，47%地區殺蟲劑使用頻繁有高程度抗藥性問題，24%地區殺蟲劑使用應屬例行性，僅具中度抗藥性，而10%地區殺蟲劑使用適當，屬低抗藥性問題困擾地區。

1. 臺灣省農業試驗所 研究報告 第 999 號。本研究爲中央加速農建補助計劃〔70 農建-5.1-產-47(02)〕承農業發展委員會及省農林廳補助研究經費，賴宗賢及周桃美協助研究工作，謹此致謝。

2. 本所應用動物系研究員。臺灣省 臺中縣 霧峰鄉。